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## Systems and Methods for Finishing a Bottle

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## **SYSTEMS AND METHODS FOR FINISHING A BOTTLE**

By: Sebastijan Jurendic

### **Technical Field**

**[0001]** The present disclosure relates to systems and methods for finishing metal containers.

### **Background**

**[0002]** Certain metal products, such as consumer product containers, food storage containers, and aluminum beverage containers, may require a finishing process including necking, threading, and brimming. For example, beverage bottles often must provide sufficient pressure restraint to contain effervescent beverages, such as sodas and colas. Suitable bottle caps can include crown cork bottle caps, flip-top bottle caps, and screw-top bottle caps.

**[0003]** In some examples, certain can body stock used in beverage cans that can be used to provide beverage bottles must undergo a plurality of additional processing steps to form a bottle neck, for example to optionally form a tamper-evident bead, to optionally form screw threads, and/or to optionally form a brim. Such a plurality of processing steps can incur higher production costs, a greater environmental impact, and increased risk of failure.

### **Summary**

**[0004]** Provided herein are methods and systems of finishing a bottle neck using electromagnetic coils. In some non-limiting examples, a method of finishing a bottle neck having a single forming step includes deploying a mold about a necked bottle preform, deploying an electromagnetic coil (e.g., an inductor coil) at least partially within the necked bottle preform, energizing the inductor coil, wherein energizing the inductor coil includes generating electromagnetic force to expand the necked bottle preform into the mold, removing

the inductor coil from the necked bottle preform, and removing the mold from about the necked bottle preform. In some aspects, deploying the mold about the necked bottle preform includes assembling a plurality of mold sections about the necked bottle preform in an automated mold deploying operation.

**[0005]** The automated mold deploying operation can further include determining that the necked bottle preform is in a forming position, and automatically assembling the plurality of mold sections about a portion of the necked bottle preform to be formed when the necked bottle preform is determined to be in the forming position. Additionally, deploying the inductor coil at least partially into the necked bottle preform can include inserting the inductor coil into a portion of the necked bottle preform to be formed (wherein the inductor coil has an outer diameter less than an inner diameter of an opening of the necked bottle preform) in an automated inductor insertion operation. In some cases, the automated inductor insertion operation includes determining that the necked bottle preform is in a forming position, and automatically inserting the inductor coil into the portion of the necked bottle preform to be formed when the necked bottle preform is determined to be in the forming position.

**[0006]** In some aspects, energizing the inductor coil includes generating an oscillating current using a driving circuit, and conveying the oscillating current through the inductor coil, wherein conveying the oscillating current through the inductor coil causes the necked bottle preform to conform to the mold.

**[0007]** In some further examples, removing the mold from the necked bottle preform includes disassembling the mold.

**[0008]** Also disclosed herein is a method of finishing a bottle neck having a single forming step, including deploying a die within a necked bottle preform, deploying an inductor coil about the necked bottle preform, energizing the inductor coil, wherein energizing the inductor coil includes generating electromagnetic force to compress the necked bottle preform

about the die, removing the inductor coil from about the necked bottle preform, and removing the die from within the necked bottle preform.

**[0009]** In some non-limiting examples, deploying the die within the necked bottle preform is an automated die deploying operation including determining that the necked bottle preform is in a forming position, and automatically deploying the die within a portion of the necked bottle preform to be formed when the necked bottle preform is determined to be in the forming position. In some cases, deploying the inductor coil about the necked bottle preform includes positioning the inductor coil about a portion of the necked bottle preform to be formed (wherein the inductor coil has an inner diameter greater than an outer diameter of the portion of the necked bottle preform to be formed) in an automated inductor deploying operation. The automated inductor deploying operation can include determining that the necked bottle preform is in a forming position, and automatically deploying the inductor coil about the portion of the necked bottle preform to be formed when the necked bottle preform is determined to be in the forming position.

**[0010]** In some aspects, energizing the inductor coil includes generating an oscillating current using a driving circuit, and conveying the oscillating current through the inductor coil, wherein conveying the oscillating current through the inductor coil causes the necked bottle preform to conform to the die.

**[0011]** Also disclosed herein is a system for finishing a bottle neck in a single forming step, including an inductor coil having an outer diameter less than an inner diameter of a portion of a necked bottle preform to be formed, an inductor coil positioning device coupled to the inductor coil to position the inductor coil with respect to the necked bottle preform, a mold deployable about the necked bottle preform, wherein the mold comprises a plurality of mold sections, wherein each mold section in the plurality of mold sections is deployable with respect to the necked bottle preform by a mold section positioning device; and a driving circuit coupled

to the inductor coil to energize the inductor coil. In some examples, the inductor coil positioning device can include a controller, a sensor coupled to the controller, wherein the sensor is positioned adjacent to the inductor coil to relay a position of the inductor coil with respect to the necked bottle preform to the controller, and a positioning arm coupled to the inductor coil to position the inductor coil with respect to the necked bottle preform. Additionally, the mold section positioning device can include a controller, a sensor coupled to the controller, wherein the sensor is positioned adjacent to the mold section to relay a position of the mold section with respect to the necked bottle preform to the controller; and a positioning arm coupled to the mold section to position the mold section with respect to the necked bottle preform.

**[0012]** In some aspects, the mold is movable between a deployed configuration and a retracted configuration, wherein the mold is adjacent the necked bottle preform in the deployed configuration, and wherein the mold is spaced apart from the necked bottle preform in the retracted configuration.

**[0013]** Also disclosed herein is a system for finishing a bottle neck in a single forming step, including an inductor coil having an outer diameter less than an inner diameter of a portion of a necked bottle preform to be formed, an inductor coil positioning device coupled to the inductor coil to position the inductor coil with respect to the necked bottle preform, a die deployable within the necked bottle preform, wherein the die is deployable with respect to the necked bottle preform by a die positioning device, and a driving circuit coupled to the inductor coil to energize the inductor coil. In some cases, the system further includes a controller, a sensor coupled to the controller, wherein the sensor is positioned adjacent to the inductor coil to relay a position of the inductor coil with respect to the necked bottle preform to the controller, and a positioning arm coupled to the inductor coil to position the inductor coil with respect to the necked bottle preform. Likewise, the die positioning device can include a controller, a

sensor coupled to the controller, wherein the sensor is positioned adjacent to the die to relay a position of the die with respect to the necked bottle preform to the controller, and a positioning arm coupled to the die to position the die with respect to the necked bottle preform. In some cases, the die is movable between a deployed configuration and a retracted configuration, wherein the die is within the necked bottle preform in the deployed configuration, and wherein the die is spaced apart from the necked bottle preform in the retracted configuration.

**[0014]** According to some examples, a method of finishing a bottle neck includes deploying a mold about a necked bottle preform, deploying an inductor coil at least partially within the necked bottle preform, and energizing the inductor coil. Energizing the inductor coil includes generating an electromagnetic force to expand the necked bottle preform into the mold, and energizing the inductor coil includes controlling at least one shaping parameter.

**[0015]** According to various examples, a system for finishing a bottle neck in a single forming step includes an inductor coil, a mold deployable about a necked bottle preform, and a controller. The controller is configured to control at least one shaping parameter such that the inductor coil generates an electromagnetic force to expand the necked bottle preform into the mold.

**[0016]** According to certain examples, a finishing control system includes an inductor coil, a sensor, and a controller communicatively coupled with the sensor and the inductor coil. The controller is configured to receive data from the sensor and control a shaping parameter of the inductor coil based on the received data while the inductor coil generates an electromagnetic force to expand a necked bottle preform into a mold.

### **Brief Description of the Drawings**

**[0017]** The specification makes reference to the following appended figures, in which use of like reference numerals in different figures is intended to illustrate like or analogous components.

**[0018]** Figure 1 is a schematic of a necked bottle preform according to certain aspects of the present disclosure.

**[0019]** Figure 2 is a schematic of an inductor coil and a mold according to certain aspects of the present disclosure.

**[0020]** Figure 3 is a schematic of the inductor coil inserted into the necked bottle preform and the mold surrounding the necked bottle preform according to certain aspects of the present disclosure.

**[0021]** Figure 4 is a schematic of the inductor coil inserted into the necked bottle preform and the mold surrounding the necked bottle preform showing forming according to certain aspects of the present disclosure.

**[0022]** Figure 5 is a schematic of the inductor coil extracted from the necked bottle preform and the mold releasing a formed bottle neck according to certain aspects of the present disclosure.

**[0023]** Figure 6 is a schematic of a finished bottle neck according to certain aspects of the present disclosure.

**[0024]** Figure 7 is a schematic of a necked bottle preform and an exemplary forming die according to certain aspects of the present disclosure.

**[0025]** Figure 8 is a schematic of a necked bottle preform subjected to a simultaneous expansive and compressive forming step according to certain aspects of the present disclosure.

**[0026]** Figure 9 illustrates an example of a finishing control system according to aspects of the present disclosure.

**[0027]** Figure 10A illustrates an example of shaping parameters controlled by the finishing control system of Figure 9 during a finishing process according to aspects of the current disclosure.

**[0028]** Figure 10B is a profile of a bottle neck formed with the shaping parameters of Figure 10A and shaped against a forming mold.

**[0029]** Figure 11A illustrates an example of shaping parameters controlled by the finishing control system of Figure 9 during a finishing process according to aspects of the current disclosure.

**[0030]** Figure 11B is a profile of a bottle neck formed with the shaping parameters of Figure 11A and shaped against a forming mold.

**[0031]** Figure 12A illustrates an example of shaping parameters controlled by the finishing control system of Figure 9 during a finishing process according to aspects of the current disclosure.

**[0032]** Figure 12B is a profile of a bottle neck formed with the shaping parameters of Figure 12A and shaped against a forming mold.

**[0033]** Figure 13A illustrates an example of shaping parameters controlled by the finishing control system of Figure 9 during a finishing process according to aspects of the current disclosure.

**[0034]** Figure 13B is a profile of a bottle neck formed with the shaping parameters of Figure 13A and shaped against a forming mold after a first time period.

**[0035]** Figure 13C is a profile of the bottle neck formed with the shaping parameters of Figure 13A and shaped against the forming mold after a second time period.

**[0036]** Figure 13D is a profile of the bottle neck formed with the shaping parameters of Figure 13A and shaped against the forming mold after a third time period.

**[0037]** Figure 14A illustrates an example of shaping parameters controlled by the finishing control system of Figure 9 during a finishing process according to aspects of the current disclosure.



**[0038]** Figure 14B is a profile of a bottle neck formed with the shaping parameters of Figure 14A and shaped against a forming mold after a first time period.

**[0039]** Figure 14C is a profile of the bottle neck formed with the shaping parameters of Figure 14A and shaped against the forming mold after a second time period.

**[0040]** Figure 14D is a profile of the bottle neck formed with the shaping parameters of Figure 14A and shaped against the forming mold after a third time period.

**[0041]** Figure 15 illustrates an example of shaping parameters controlled by the finishing control system of Figure 9 during a finishing process according to aspects of the current disclosure.

**[0042]** Figure 16 illustrates profiles of bottle necks formed with the shaping parameters of Figure 15 and shaped against a forming mold.

**[0043]** Figure 17 illustrates profiles of bottle necks formed using the finishing control system of Figure 9 and shaped against a forming mold by controlling shaping parameters during a finishing process according to aspects of the current disclosure.

### **Detailed Description**

**[0044]** Certain aspects and features of the present disclosure relate to systems and methods for finishing a metal consumer product container. In some examples, finishing a metal consumer product container, such as a bottle, can require a plurality of forming steps. Provided herein are systems and methods to significantly reduce forming steps to finish a metal container such as, but not limited to, a bottle. In some examples, the disclosed methods and systems reduce the steps for finishing a bottle neck.

**[0045]** In some non-limiting examples, methods and systems of finishing a bottle neck can include positioning a necked bottle preform created from an electrically conductive material (e.g., metals, conductive polymers, semi-conductive polymers, composites, any

suitable conductive material, or any combination thereof) into a mold, inserting a forming coil of a forming circuit into the necked bottle preform, and energizing the forming coil.

**[0046]** Applying current to energize the forming coil can include using a tuned or tunable forming circuit to supply energy to the forming coil. A tuned or tunable forming circuit can include one or more inductors (e.g., the forming coil and/or a tuning coil), one or more capacitors, and optionally one or more resistors. Certain circuit elements, such as capacitors, resistors, or inductors (e.g., a tuning coil) may be adjustable to permit adjustability in the tuning of the forming circuit, although that need not be the case, and some or all circuit elements may be non-adjustable such that the forming circuit maintains a preset tuning. Tuning of the forming circuit can refer to the characteristics of the current it outputs, such as the current, voltage, and frequency of the output current. In a charging step, the capacitor/plurality of capacitors can be isolated from the remainder of the forming circuit by a switch, such as an electrical switch (e.g., a manually operated button or automatic actuator-operated electrical switch) or an electronic switch (e.g., a transistor, such as a field effect transistor). The capacitor/plurality of capacitors can be electrically charged from a voltage source, such as to a set amount of energy (e.g., from about 0.1 kiloJoules (kJ) to about 100 kJ, or from about 0.1 microFarads ( $\mu\text{F}$ ) to about 200  $\mu\text{F}$ ). During forming, the capacitor/plurality of capacitors can be connected to the remainder of the forming circuit by activating the switch. Activating the switch can allow the capacitor/plurality of capacitors to discharge energy through the forming coil. The forming circuit can be tuned by changing at least one of capacitance, inductance, and resistance of any electrical components. The forming circuit can be tuned to provide an oscillating current having a frequency of from about 1 kiloHertz (kHz) to about 100 kHz. For example, tuning the forming circuit can provide a forming circuit that is optimized for a specific material, application, or any suitable forming requirement. In some examples, energizing the forming coil can further apply an electromagnetic force to the necked bottle preform.

**[0047]** Applying the electromagnetic force to the necked bottle preform can form the necked bottle preform. Forming the necked bottle preform can have a forming direction including expanding the necked bottle preform when the forming coil is inserted within the necked bottle preform and/or compressing the necked bottle preform when the forming coil is positioned about the necked bottle preform. Forming the necked bottle preform can include using the electromagnetic field of the forming coil to urge the necked bottle preform towards and/or into a die or mold, thus forming the necked bottle preform into a desired shape. Once the necked bottle preform is formed, the forming coil can be removed from within the necked bottle preform, and the necked bottle preform can be removed from the mold.

**[0048]** In some aspects, the necked bottle preform includes a preform for any consumer product container including, but not limited to, a beverage container, a jar, a low-form container, a wide-mouth container, a narrow-mouth container, a vial, a paint can, or any suitable product container. Figure 1 shows a schematic illustration of a necked bottle preform 110 according to one example described herein. The necked bottle preform 110 can include sections that can be threaded 120 (e.g., to receive a screw-on enclosure), sections that can be brim rolled 130 (e.g., to receive a crown cap enclosure or seal a screw-on enclosure), sections that can be beaded (e.g., to allow tamper-evident mechanism to be incorporated) and/or sections that can be formed for aesthetic elements (not shown). The necked bottle preform 110 may be aluminum or any suitable conductive metal.

**[0049]** Positioning the necked bottle preform 110 within the mold can be performed by automatically assembling a multi-section mold about the necked bottle preform. The mold can include a plurality of mold sections that can be assembled to form the mold. Figure 2 is a schematic illustration of a system for finishing a bottle neck according to one example. A multi-section mold 210 and forming coil 220 can be employed to finish a bottle neck. Each mold section 215 of the multi-section mold 210 can be attached to a positioning device (e.g., a

positioning arm) capable of deploying the mold section 215 about the necked bottle preform 110. The positioning device can be controlled manually or automatically by a positioning system. When employing a positioning system, a sensor (e.g., an optical sensor, a magnetic sensor, a thermal sensor, a pressure sensor, any suitable sensor, or any combination thereof) can be positioned adjacent to the mold section 215 such that the sensor can relay information to a controller controlling deployment of the mold section 215 to create the multi-section mold 210.

**[0050]** Figure 3 is a schematic illustration showing the necked bottle preform 110 surrounded by the multi-section mold 210. The multi-section mold can be assembled about the necked bottle preform 110. The forming coil 220 can be inserted into the necked bottle preform 110 to a position adjacent to a section of the necked bottle preform 110 to be formed (e.g., a section to be threaded 120). As in the example of the multi-section mold 210, the forming coil 220 can be controlled manually or automatically employing a positioning system. When employing a positioning system, a sensor (e.g., an optical sensor, a magnetic sensor, a thermal sensor, a pressure sensor, any suitable sensor, or any combination thereof) can be positioned adjacent to the forming coil 220 such that the sensor can relay information to a controller controlling deployment of the forming coil 220 within the necked bottle preform 110.

**[0051]** In some aspects, forming is performed by applying a voltage to energize at least the capacitor, activating the switch, and energizing the forming coil 220. In some examples, energizing the circuit can include providing an oscillating current having a frequency of from about 1 kHz to about 100 kHz. Applying the oscillating current to the forming coil 220 can further apply an electromagnetic force to the necked bottle preform 110. Not to be bound by theory, the electromagnetic force can include an electromagnetic field that can induce eddy currents in a necked bottle preform comprising a conductive material. The eddy currents can generate Lorentz forces forcing the conductive material to deform. In some non-limiting

examples, forming the necked bottle preform can have a forming direction including expanding the necked bottle preform outward when the inductor coil is inserted into the necked bottle preform.

**[0052]** Figure 4 is a schematic illustration showing a formed bottle neck 410. The necked bottle preform 110 (see Figure 1) is expanded into the multi-section mold 210 by electromagnetic force applied by the forming coil 220 and can take on a shape determined by the multi-section mold 210. In some aspects, the multi-section mold 210 can impress a spiral thread structure 420 onto the necked bottle preform 110 providing a threaded formed bottle neck 410.

**[0053]** Figure 5 is a schematic illustration depicting removal of the multi-section mold 210 from the formed bottle neck 410. The multi-section mold 210 can be disassembled and the forming coil 220 can be extracted from the formed bottle neck 410. As described above, disassembling the multi-section mold 210 and/or retracting the forming coil 220 can be performed manually, or automatically employing a positioning system. Figure 6 is a schematic illustration of the formed bottle neck 410.

**[0054]** In some non-limiting examples, the method of forming the bottle neck can further include inserting a die (e.g., a mandrel) into the necked bottle preform and positioning an inductor coil about a section of the necked bottle preform to be formed. An exemplary method is illustrated in Figure 7.

**[0055]** A multi-section die 700 can include a plurality of die sections 710, wherein the plurality of die sections 710 can be assembled to form the multi-section die 700 within the necked bottle preform 110. Each die section 710 can have a width 720 less than a diameter of an opening 730 of the necked bottle preform 110. Assembling the multi-section die 700 within the necked bottle preform 110 can include inserting the plurality of die sections 710 sequentially (see block 740) into the necked bottle preform 110 beyond a section of the necked

bottle preform 110 to be formed (e.g., beyond a neck of a bottle into a body of the bottle having a larger inner diameter than the neck of the bottle). The die sections 710 can be retracted to the section of the necked bottle preform 110 to be formed in a sequence, wherein a first die section can be retracted to the section of the necked bottle preform 110 to be formed and at least a second die section can be retracted to the section of the necked bottle preform 110 to be formed and pressed against the first die section to assemble the multi-section die 700. The multi-section die 700 can be maintained in an assembled state during forming. As described above, deploying the multi-section die 700 and/or the forming coil 220 can be performed manually, or automatically employing a positioning system.

**[0056]** In some cases, the die can be an expandable die that can be inserted into the necked bottle preform in a collapsed state, expanded into a deployed state, maintained in the deployed state for electromagnetic forming, contracted to the collapsed state after electromagnetic forming and extracted from the necked bottle preform. Deploying and extracting the expandable die can be an automated procedure.

**[0057]** Positioning a forming coil about the necked bottle preform can include inserting a section of the necked bottle preform to be formed into the forming coil (not shown) having an inner diameter greater than an outer diameter of the necked bottle preform 110. In some aspects, forming is performed by applying a voltage to energize the forming circuit. Applying voltage to the forming circuit can further apply an electromagnetic force to the necked bottle preform 110 within the forming coil. In some non-limiting examples, forming the necked bottle preform 110 can have a forming direction including compressing the necked bottle preform 110 inward when the inductor coil is positioned about the necked bottle preform 110. The necked bottle preform 110 can be collapsed onto the multi-section die 700 by electromagnetic force applied by the inductor coil and can take on a shape determined by the multi-section die 700 providing a formed bottle neck 410 (see Figure 6).

**[0058]** Disassembling the multi-section die 700 can include releasing the assembled multi-section die 700, inserting the plurality of die sections 710 sequentially beyond the section to be formed, and extracting the plurality of die sections 710 sequentially (see block 740) from the formed bottle neck 410. As described above, disassembling the multi-section die 700 and/or retracting the forming coil 220 can be performed manually, or automatically employing a positioning system.

**[0059]** In some non-limiting examples the methods described herein can be a method of finishing a bottle that includes a single forming step such as electromagnetic forming. In some cases, finishing a bottle neck can employ several steps to form finish features including threads, brim rolls, safety features, aesthetic features, and any features suitable for a bottle neck. Electromagnetic forming can include applying an electromagnetic force to a necked bottle preform to form one or more of a neck, threads, a first stage of a brim roll, aesthetic elements, or any suitable finishing forming step. The electromagnetic forming can be expansive or compressive as described above.

**[0060]** In some cases, electromagnetic forming can include applying an electromagnetic force to a metal container preform for necking a bottle. A cylindrical bottle preform can be subjected to the systems and methods described above. The electromagnetic forming can be an expansive force or a compressive force as described above. In some cases, the systems and methods described herein can provide a necked bottle preform 110 (see Figure 1).

**[0061]** In some non-limiting examples, electromagnetic forming can include simultaneously applying the expansive force and the compressive force. The expansive force can act as an electromagnetic die (i.e., the inserted inductor coil pushes the bottle material outward) and the compressive force can act as an electromagnetic mold (i.e., the surrounding inductor coil pushes the bottle material inward), or vice versa. In the example of Figure 8, the

forming coil 220 can be inserted into the necked bottle preform 110, and a compressive forming coil 810 can simultaneously be positioned about at least an exterior portion of the necked bottle preform 110. Simultaneously applying an expansive force and a compressive force can provide highly complex shapes. In some non-limiting examples, expansive force and compressive force can be applied in an alternating sequence to provide, for example, a convoluted shape. The alternating sequence can be controlled to provide any combination of expansive force and compressive force. In some further examples, the forming coil 220 and the compressive forming coil 810 can be moved relative to the necked bottle preform 110 to provide a dynamic forming step further providing highly complex shapes. For example, the forming coil 220 and the compressive forming coil 810 can be withdrawn from the necked bottle preform 110 during a forming operation to provide, for example, a curved shape.

**[0062]** In some non-limiting examples, finishing a bottle neck can include several processing steps including one or more of bead expansion, threading, necking after threading and a 2-stage curling process. The systems and methods described can simplify a finishing process by requiring fewer forming steps to arrive at a finished bottle neck. The methods described herein can further simplify a finishing process by requiring simpler tooling, wherein the tooling can have fewer moving parts and fewer process parameters for control. Additionally, the systems and methods described herein can provide minimal effect on coatings applied to a product side of a container produced from the necked bottle preform. For example, protecting product-side coatings can reduce the possibility of any contents of the container contacting an area of exposed metal of the container (e.g., a beverage directly contacting aluminum). In some further examples, the systems and methods described herein can reduce and/or eliminate a requirement for lubrication. In some non-limiting examples, the systems and methods described herein can provide an ability to simultaneously perform a heat-treatment (e.g., form and anneal a bottle neck simultaneously). For example, operating the forming coil



at a high frequency (e.g., greater than about 1 kHz) for a sustained period of time (e.g., for about 0.1 seconds or greater) can heat the necked bottle preform to perform a warm forming procedure.

**[0063]** In some cases, the systems and methods described herein can improve a finishing process by providing improved geometrical stability of a formed product. For example, a necked bottle preform (e.g., a necked bottle preform comprising a conductive material) can be formed against a solid structure (e.g., a mold, a die, or a mandrel) that determines a desired geometry. Forming the necked bottle preform against a solid structure can provide a process having parameters with a decreased influence on the forming.

**[0064]** In some aspects, the systems and methods described herein can provide formed products having improved axial load performance. In some non-limiting examples, more accurately and precisely produced products can exhibit improved buckle performance under axial load and reduce variability from product to product (e.g., from bottle to bottle). Higher control can further provide opportunity for down-gauging raw materials used in the methods described herein. For example, thinner gauge aluminum sheets can be employed in a bottle making process using the methods described herein.

**[0065]** In some examples, the systems and methods described herein can provide improved limits of formability. For example, electromagnetic forces can be applied uniformly to a product being formed. Electromagnetic forces can act uniformly throughout the conductive material of the necked bottle preform as opposed to mechanical forming processes that apply forces only at a material surface.

**[0066]** Figure 9 illustrates an example of a finishing control system 900 according to aspects of the current disclosure. As previously referenced, the finishing control system 900 includes a controller 902, at least one sensor 904, and a forming coil 906 that are communicatively coupled. Although not illustrated in Figure 9, the mold or mold sections

discussed above may also be communicatively coupled with the finishing control system 900. The forming coil 906 may be substantially similar to the forming coil 220, the forming coil 810, and/or may have various other designs or configurations as desired. The sensor 904 may be various suitable types of sensors for detecting various shaping conditions such that a shaping parameter can be controlled as desired. The sensor 904 may also be various input devices suitable for receiving input (e.g., a desired temperature distribution profile, a desired shape, etc.) from an operator or some other source. For example, the sensor 904 may include, but is not limited to, an optical sensor, a magnetic sensor, an energy sensor, a current sensor, a frequency detector, a thermal sensor, a pressure sensor, any suitable sensor, a device with a user interface, or any combination thereof.

**[0067]** The controller 902 can include one or more of a general purpose processing unit, a processor specially designed for finishing control analysis and/or finishing control applications, a processor specially designed for wireless communications (such as a Programmable System On Chip from Cypress Semiconductor or other suitable processors). A memory may be provided with the controller 902, although it need not in other examples. The memory may include a long-term storage memory and/or a short-term working memory. The memory may be used by the controller 902 to store a working set of processor instructions. The processor may write data to the memory. The memory may include a traditional disk device. In some aspects, the memory could include either a disk based storage device or one of several other type storage mediums to include a memory disk, USB drive, flash drive, remotely connected storage medium, virtual disk drive, or the like. Various other features including, but not limited to, a communication circuit/unit, an optional display, an optional speaker, and/or power storage unit may also be included in the controller 902. In some aspects, some or all of the components of the controller 902 may be included together in a single package or sensor suite, such as within the same enclosure. In additional or alternative aspects, some of the

components may be included together in an enclosure and the other components may be separate. Thus, the controller 902 may be a distributed system. This is merely one example and other configurations may be implemented.

**[0068]** In various aspects, the controller 902 communicates data with the sensor 904 such that the controller 902 receives a data signal from the sensor 904. In various aspects, the data signal from the sensor 904 includes a temperature profile on the bottle preform, a current, a voltage, a shape, energy, frequency of the current, and/or various other suitable measurements or data. The controller 902 can analyze the data from the sensor 904 and control one or more shaping parameters (e.g., parameters that affect the shaping and forming of the bottle neck against the mold) to control the shaping of the bottle neck preform against the mold. In other examples, the controller 902 can control the one or more shaping parameters based on input received prior to the forming process. Shaping parameters include, but are not limited to, the current provided to the forming coil, the frequency of the current that is provided to the forming coil, the duration for which the current is provided to the forming coil, the energy provided to the forming coil, combinations thereof, or various other suitable shaping parameters. Additionally or alternatively, the finishing control system 900 controls the one or more shaping parameters to provide a desired temperature distribution on the bottle neck preform as it is being shaped during the finishing process. In some cases, the desired temperature distribution on the bottle neck preform provides improved control over shaping and forming because the bottle neck preform is warmed and more workable.

**[0069]** Figures 10A-14D illustrate various examples of how the finishing control system 900 controls one or more shaping parameters to control the shaping of the bottle neck.

**[0070]** Figure 10A is a chart illustrating an example of the finishing control system 900 controlling the finishing process by operating the forming coil 906 at a frequency of 2000 Hz and over a period of time with a current as represented by the curve 1000. Figure 10B illustrates

a bottle neck 1002 shaped against a mold 1004 according to the curve 1000 illustrated in Figure 10A. In particular, Figure 10B illustrates the bottle neck 1002 after 0.039997 ms.

**[0071]** Figure 11A is a chart illustrating an example of the finishing control system 900 controlling the finishing process by operating the forming coil 906 at a frequency of 850 Hz and over a period of time with a current as represented by the curve 1100. The curve 1000 is also provided for reference purposes. Figure 11B illustrates a bottle neck 1102 shaped against the mold 1004 as a result of the finishing process according to the curve 1100 illustrated in Figure 11A. In particular, Figure 11B illustrates the bottle neck 1102 after 0.16 ms. By comparing Figure 11B with Figure 10B and curve 1100 with curve 1000, by controlling the frequency, current, and duration, the finishing control system 900 can control the finishing process to produce bottle necks 1002, 1102 having different profiles.

**[0072]** Figure 12A is a chart illustrating an example of the finishing control system 900 controlling the finishing process by operating the forming coil 906 at a frequency of 500 Hz and over a period of time with a current as represented by the curve 1200. The curve 1200 is different from the curve 1000 and the curve 1100. The curve 1000 is provided in Figure 12A for reference purposes. Figure 12B illustrates a bottle neck 1202 shaped against the mold 1004 as a result of the finishing process according to the curve 1200 illustrated in Figure 12A. In particular, Figure 12B illustrates the bottle neck 1202 after 0.42 ms. By comparing Figure 12B with Figure 10B and curve 1200 with curve 1000, by controlling the frequency, current, and duration (among others), the finishing control system 900 can control the finishing process to produce bottle necks 1002, 1202 having different profiles.

**[0073]** Figure 13A is a chart illustrating an example of the finishing control system 900 controlling the finishing process by operating the forming coil 906 at a frequency of 7000 Hz and over a period of time with a current as represented by the curve 1300. The curve 1300 is different from the curves 1000, 1100, and 1200. The curve 1000 is provided in Figure 13A for

reference purposes. Figures 13B-D illustrates a bottle neck 1202 shaped against the mold 1004 at various time periods as a result of the finishing process according to the curve 1300 illustrated in Figure 13A. In particular, Figure 13B illustrates the bottle neck 1302 after 0.14 ms, Figure 13C illustrates the bottle neck 1302 after 0.039997 ms, and Figure 13D illustrates the bottle neck 1302 after 0.099996 ms. By comparing Figures 13B-D with Figure 10B and curve 1300 with curve 1000, by controlling the frequency, current, and duration (among others), the finishing control system 900 can control the finishing process to produce bottle necks 1002, 1302 having different profiles.

**[0074]** Figure 13A is a chart illustrating an example of the finishing control system 900 controlling the finishing process by operating the forming coil 906 at a frequency of 7000 Hz and over a period of time with a current as represented by the curve 1300. The curve 1300 is different from the curves 1000, 1100, and 1200. The curve 1000 is provided in Figure 13A for reference purposes. Figures 13B-D illustrates a bottle neck 1302 shaped against the mold 1004 at various time periods as a result of the finishing process according to the curve 1300 illustrated in Figure 13A. In particular, Figure 13B illustrates the bottle neck 1302 after 0.14 ms, Figure 13C illustrates the bottle neck 1302 after 0.039997 ms, and Figure 13D illustrates the bottle neck 1302 after 0.099996 ms. By comparing Figures 13B-D with Figure 10B and curve 1300 with curve 1000, by controlling the frequency, current, and duration (among others), the finishing control system 900 can control the finishing process to produce bottle necks 1002, 1302 having different profiles.

**[0075]** Figure 14A is a chart illustrating an example of the finishing control system 900 controlling the finishing process by operating the forming coil 906 at a frequency of 45000 Hz and over a period of time with a current as represented by the curve 1400. The curve 1400 is different from the curves 1000, 1100, 1200, and 1300. The curve 1000 is provided in Figure 13A for reference purposes. Figures 14B-D illustrates a bottle neck 1402 shaped against the

mold 1004 at various time periods as a result of the finishing process according to the curve 1400 illustrated in Figure 14A. In particular, Figure 14B illustrates the bottle neck 1402 after 0.09997 ms, Figure 14C illustrates the bottle neck 1402 after 0.019997 ms, and Figure 14D illustrates the bottle neck 1402 after 0.059997 ms. By comparing Figures 14B-D with Figure 10B and curve 1400 with curve 1000, by controlling the frequency, current, and duration (among others), the finishing control system 900 can control the finishing process to produce bottle necks 1002, 1402 having different profiles.

**[0076]** Figures 15 and 16 illustrate various examples of how the finishing control system 900 controls one or more shaping parameters to control the temperature of the bottle neck during the finishing process, which can be used to control the shaping. In other examples, controlling the temperature may perform heat treatment or control the bottle forming process in other aspects.

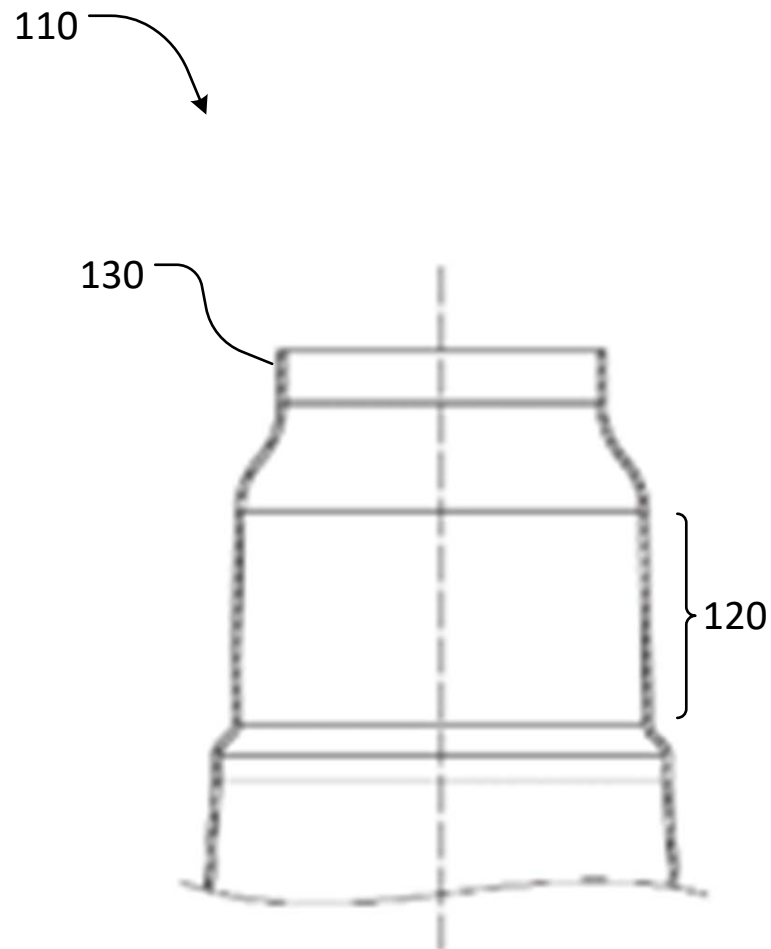
**[0077]** In Figure 15, curve 1502 represents the temperature from the forming coil on the bottle neck when the forming coil was operated at a frequency of 2000 Hz with the current profile 1000 illustrated in Figure 10A for the predetermined period of time. The maximum temperature of curve 1502 was 142 °C. Curve 1504 represents the temperature from the forming coil on the bottle neck when the forming coil was operated at a frequency of 850 Hz with the current profile 1100 illustrated in Figure 11A for the predetermined period of time. The maximum temperature of curve 1504 was 86 °C. Curve 1506 represents the temperature from the forming coil on the bottle neck when the forming coil was operated at a frequency of 500 Hz with the current profile 1200 illustrated in Figure 12A for the predetermined period of time. The maximum temperature of curve 1506 was 63 °C. Curve 1508 represents the temperature from the forming coil on the bottle neck when the forming coil was operated at a frequency of 7000 Hz with the current profile 1300 illustrated in Figure 13A for the predetermined period of time. The maximum temperature of curve 1508 was 133 °C. Curve

1510 represents the temperature from the forming coil on the bottle neck when the forming coil was operated at a frequency of 45000 Hz with the current profile 1400 illustrated in Figure 14A. The maximum temperature of curve 1510 was 160 °C.

**[0078]** Figure 16 illustrates the temperature distribution profiles on the bottle necks 1002, 1102, 1202, 1302, and 1402 based on the temperatures illustrated in Figure 15. As illustrated in Figure 16, by controlling the shaping parameters such as frequency, current, and duration (among others), the finishing control system 900 can produce bottle necks having a desired temperature profile and/or shape.

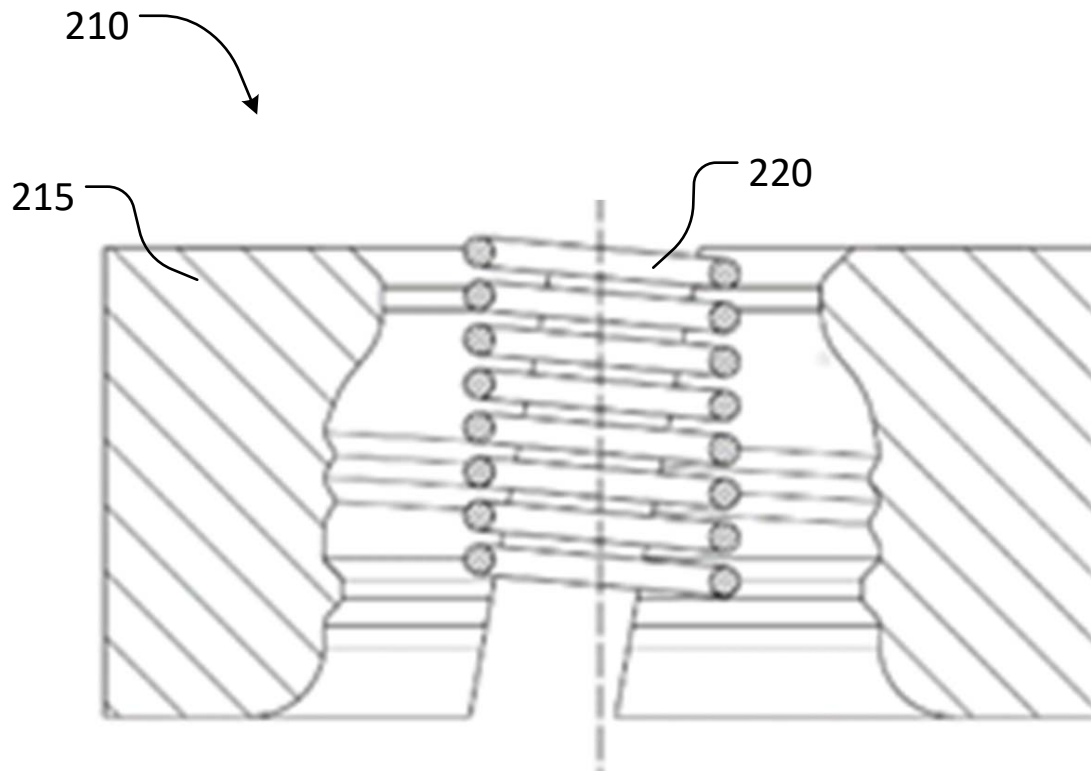
**[0079]** Figure 17 illustrates examples of bottle necks 1702-1710 formed by the finishing control system 900 by controlling the energy provided to the forming coil and the frequency of the forming coil. For example, the bottle neck 1702 was formed with a forming coil that was supplied with 36 kJ and operating at a frequency of 2000 Hz, bottle neck 1704 was formed with a forming coil that was supplied with 108 kJ and operating at a frequency of 850 Hz, bottle neck 1706 was formed with a forming coil that was supplied with 200 kJ and operating at a frequency of 500 Hz, bottle neck 1708 was formed with a forming coil that was supplied with 4.8 kJ and operating at a frequency of 7000 Hz, and bottle neck 1710 was formed with a forming coil that was supplied with 31 kJ and operating at a frequency of 45000 Hz. As illustrated in Figure 17, by controlling the shaping parameters such as energy and frequency, the finishing control system 900 can produce bottle necks having a desired shape.

**[0080]** It will be appreciated that the examples illustrated in Figures 10A-17 are provided for illustrative purposes only and should not be considered limiting on the current disclosure. In other examples, the finishing control system 900 can control various combinations of shaping parameters and/or various combinations of values of shaping parameters to produce bottle necks having desired shapes and/or desired temperature distributions.

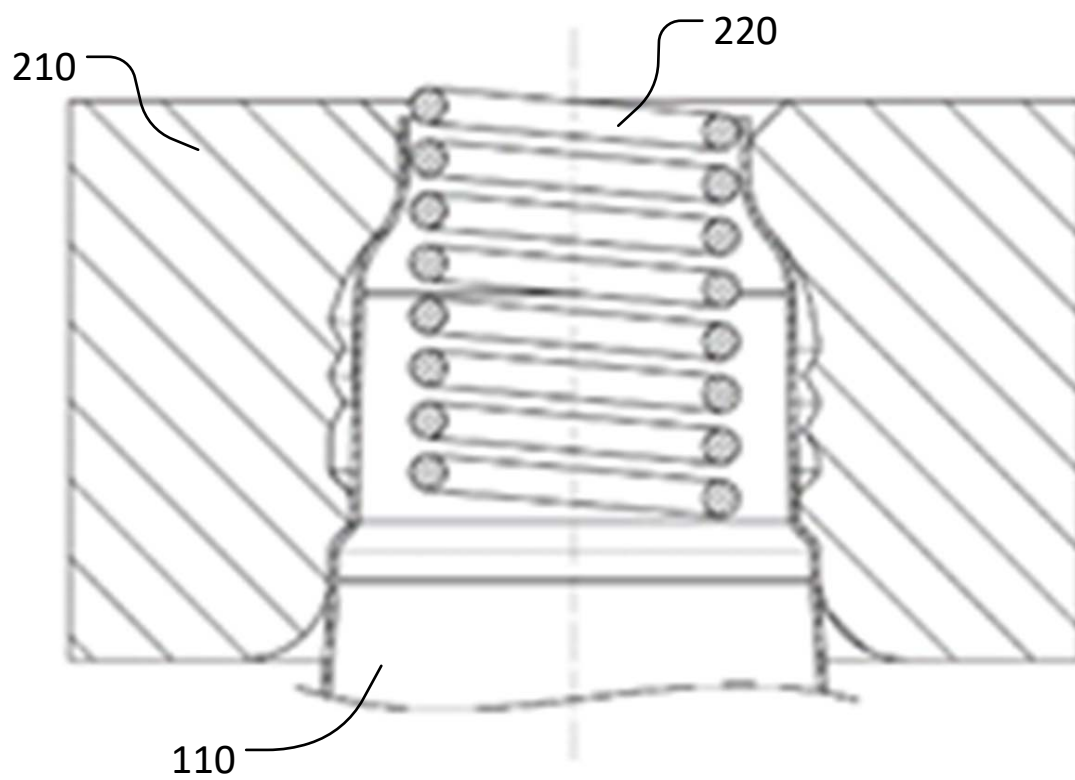


**FIG. 1**

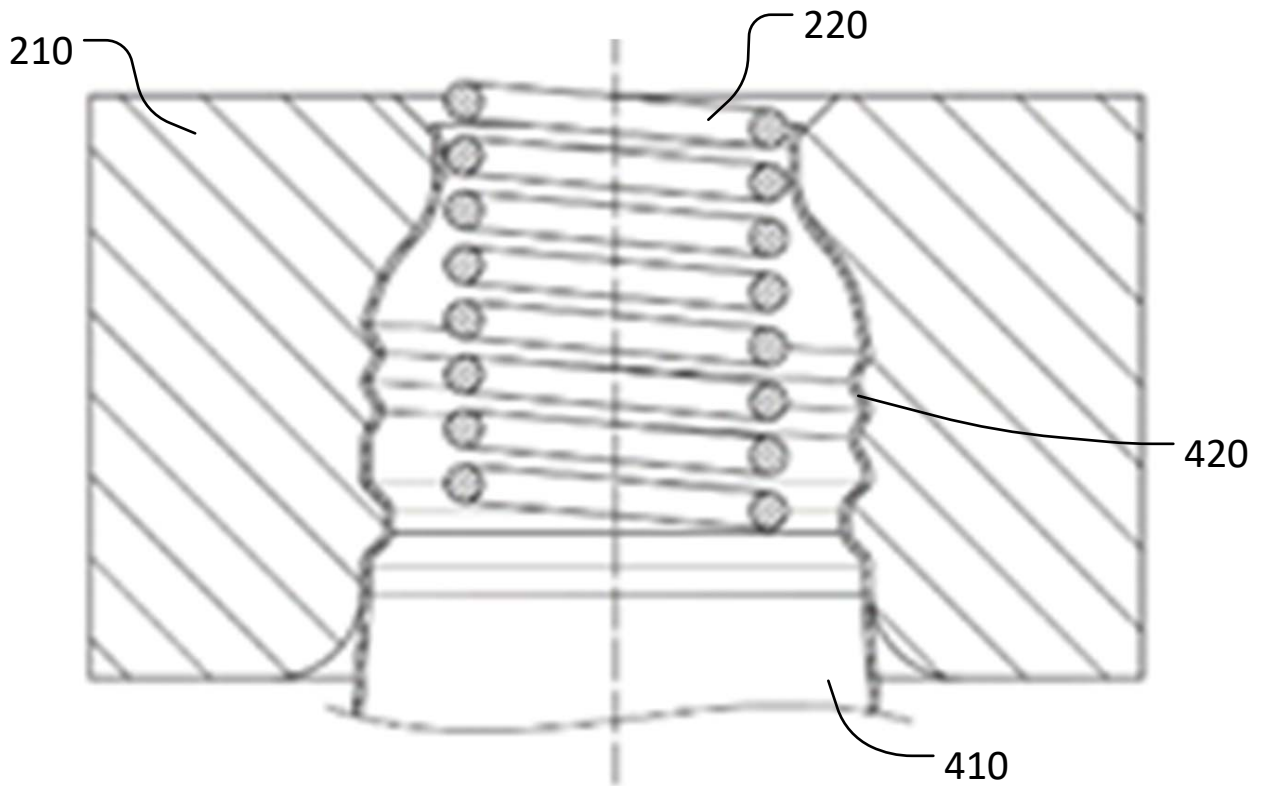




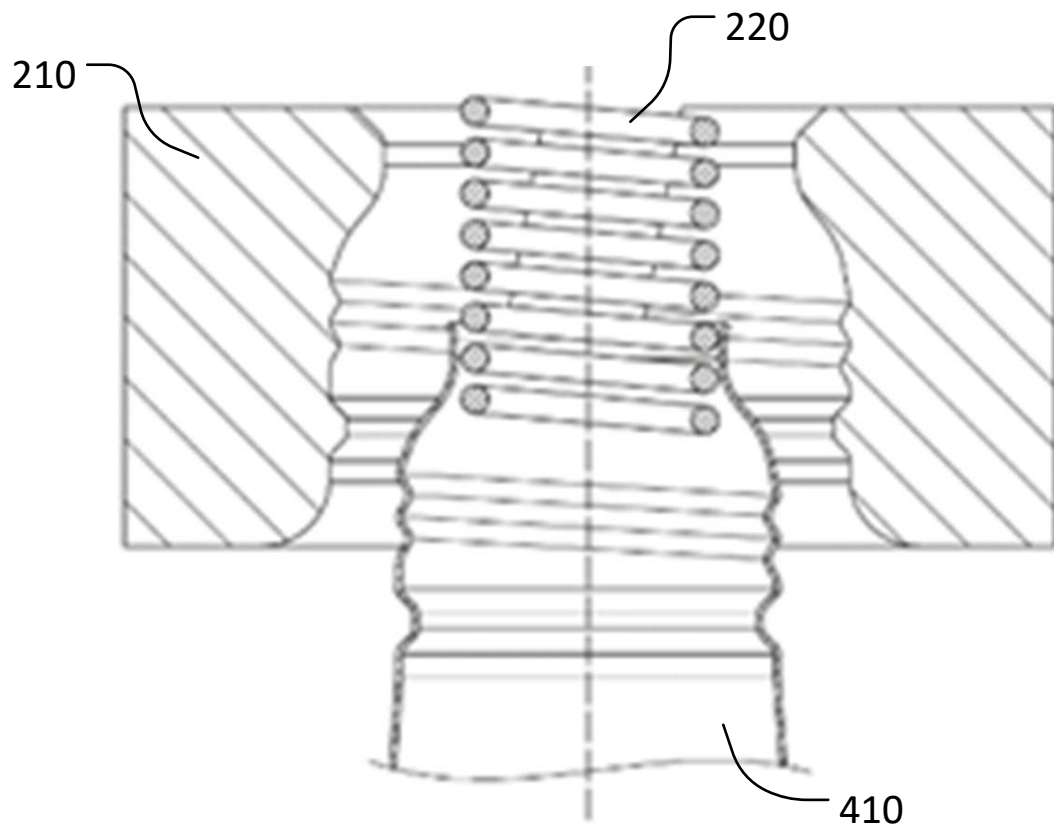
**FIG. 2**



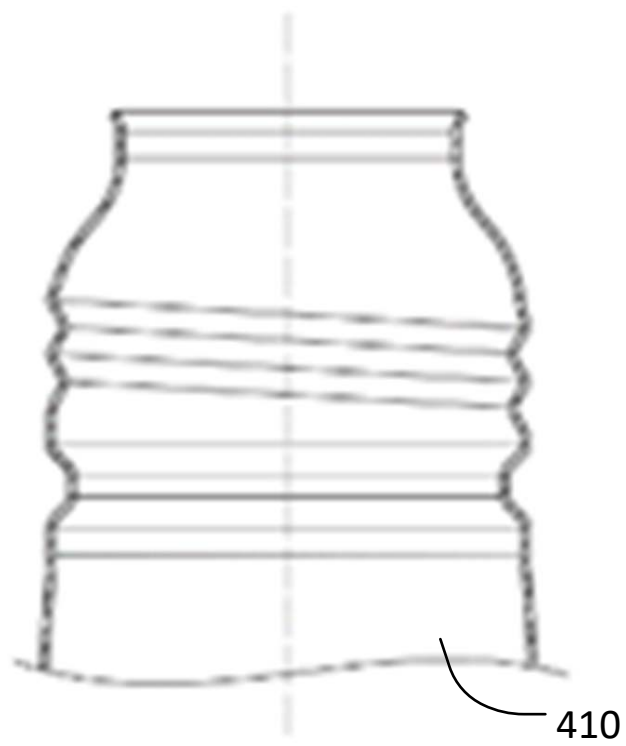
**FIG. 3**



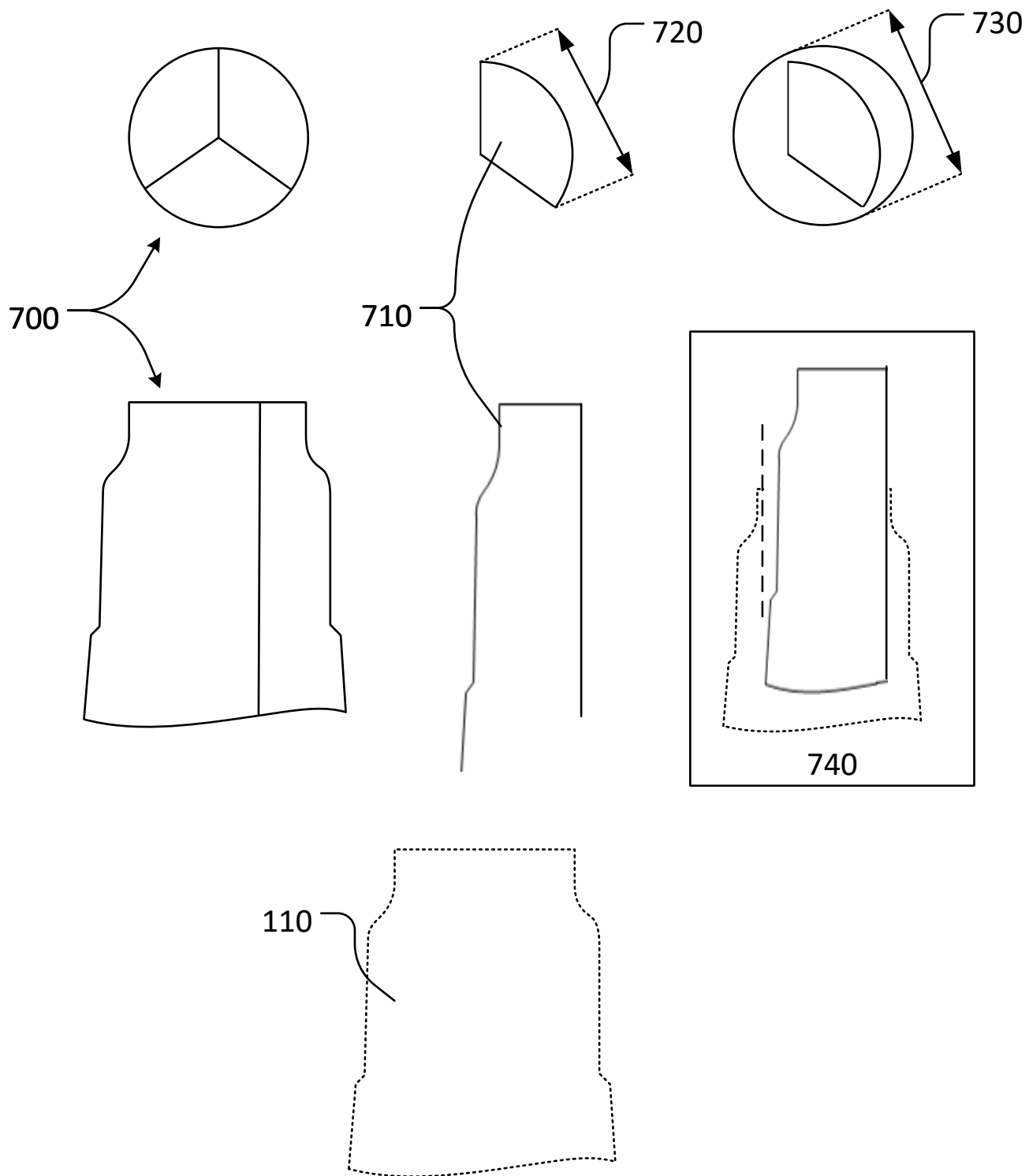
**FIG. 4**



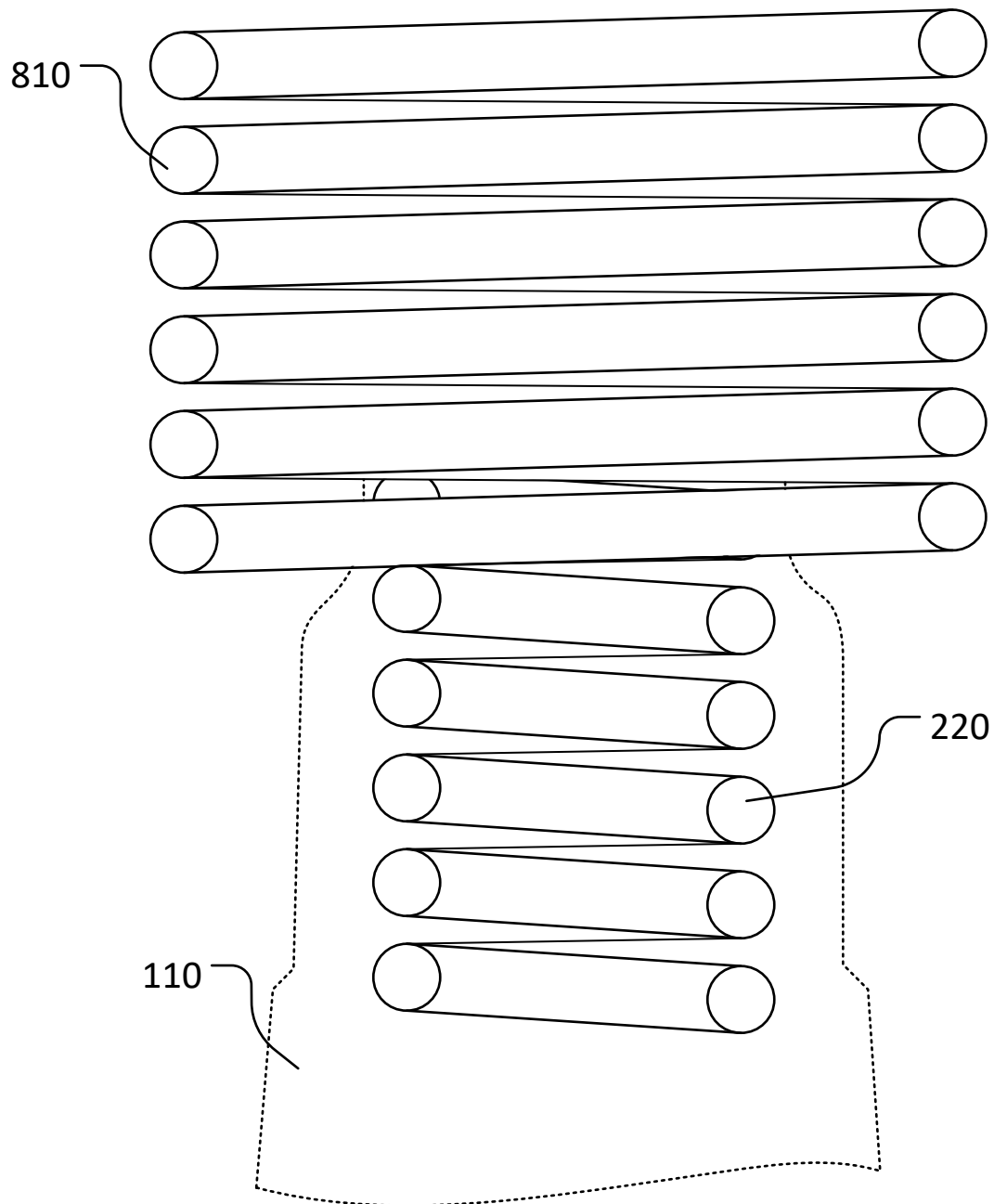
*FIG. 5*



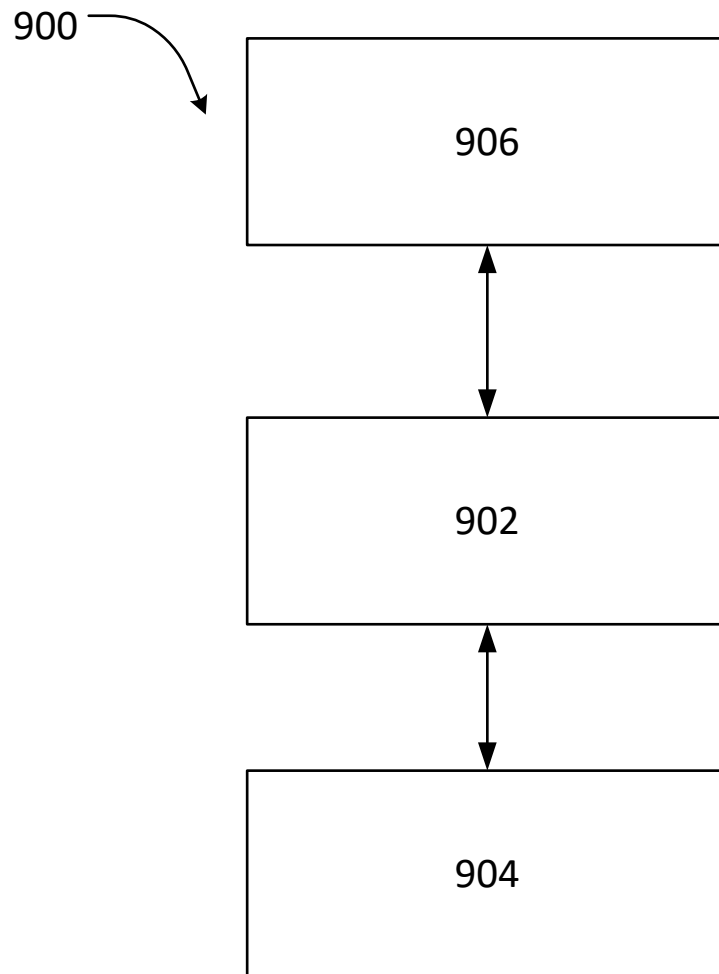
**FIG. 6**



**FIG. 7**



**FIG. 8**



*FIG. 9*



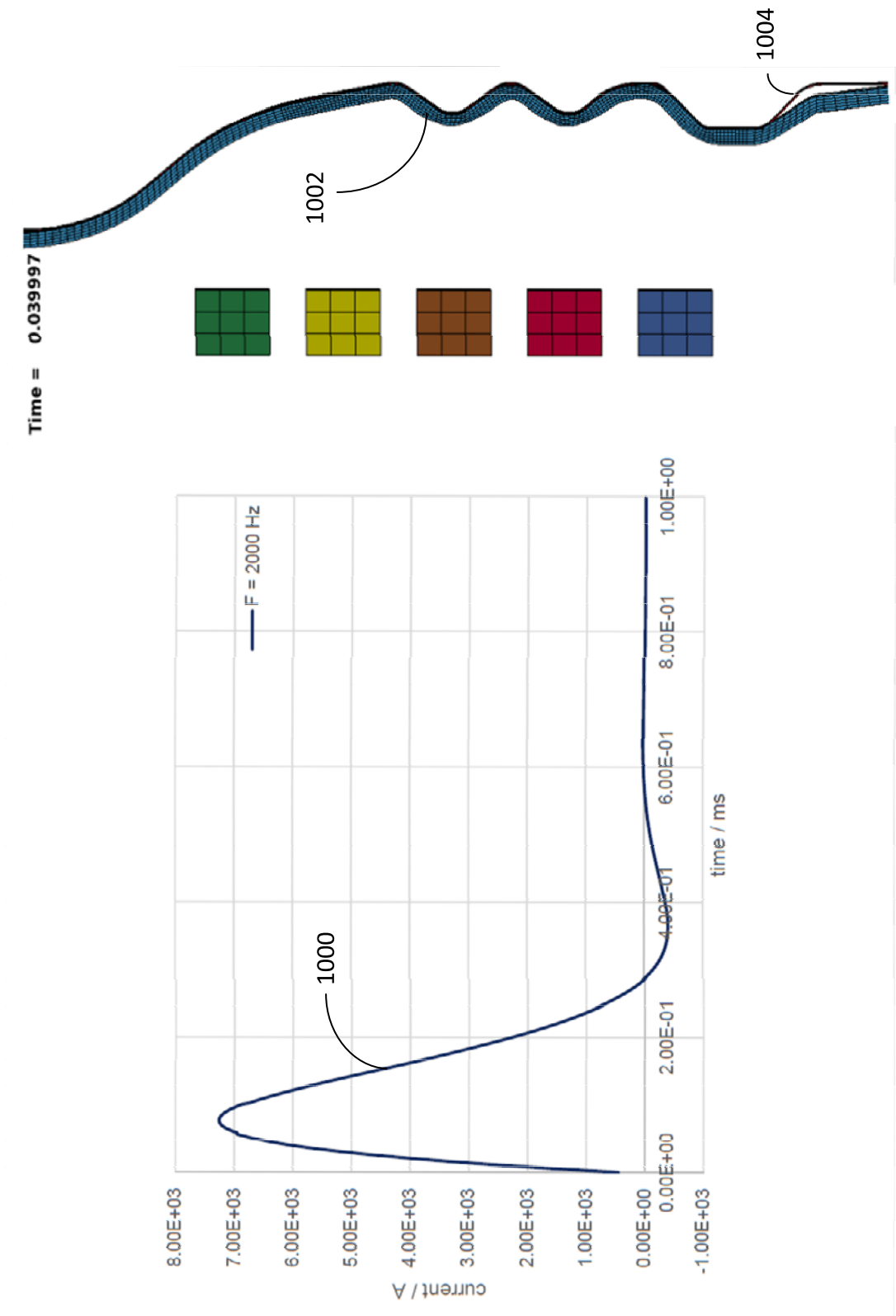


FIG. 10A

FIG. 10B

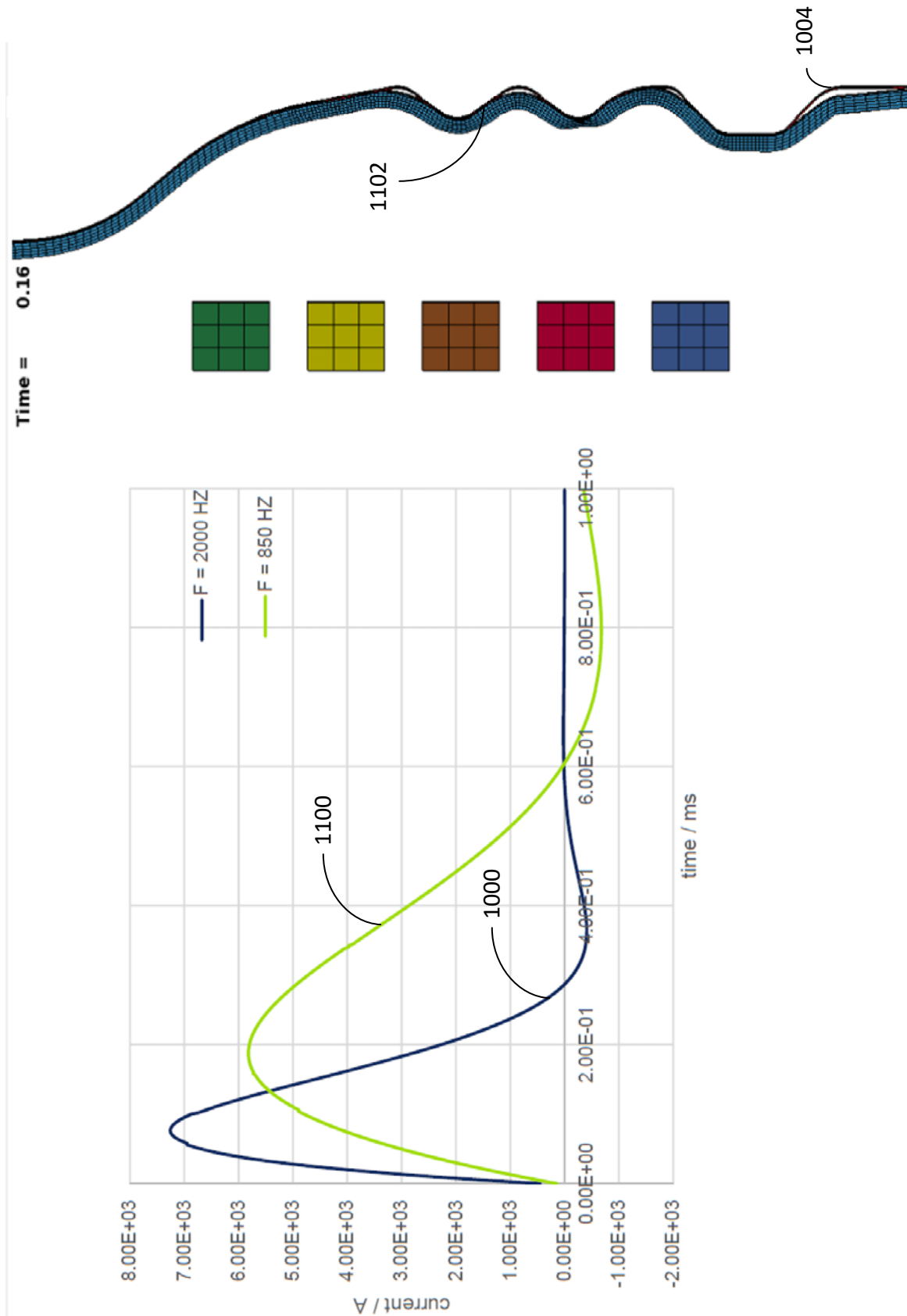
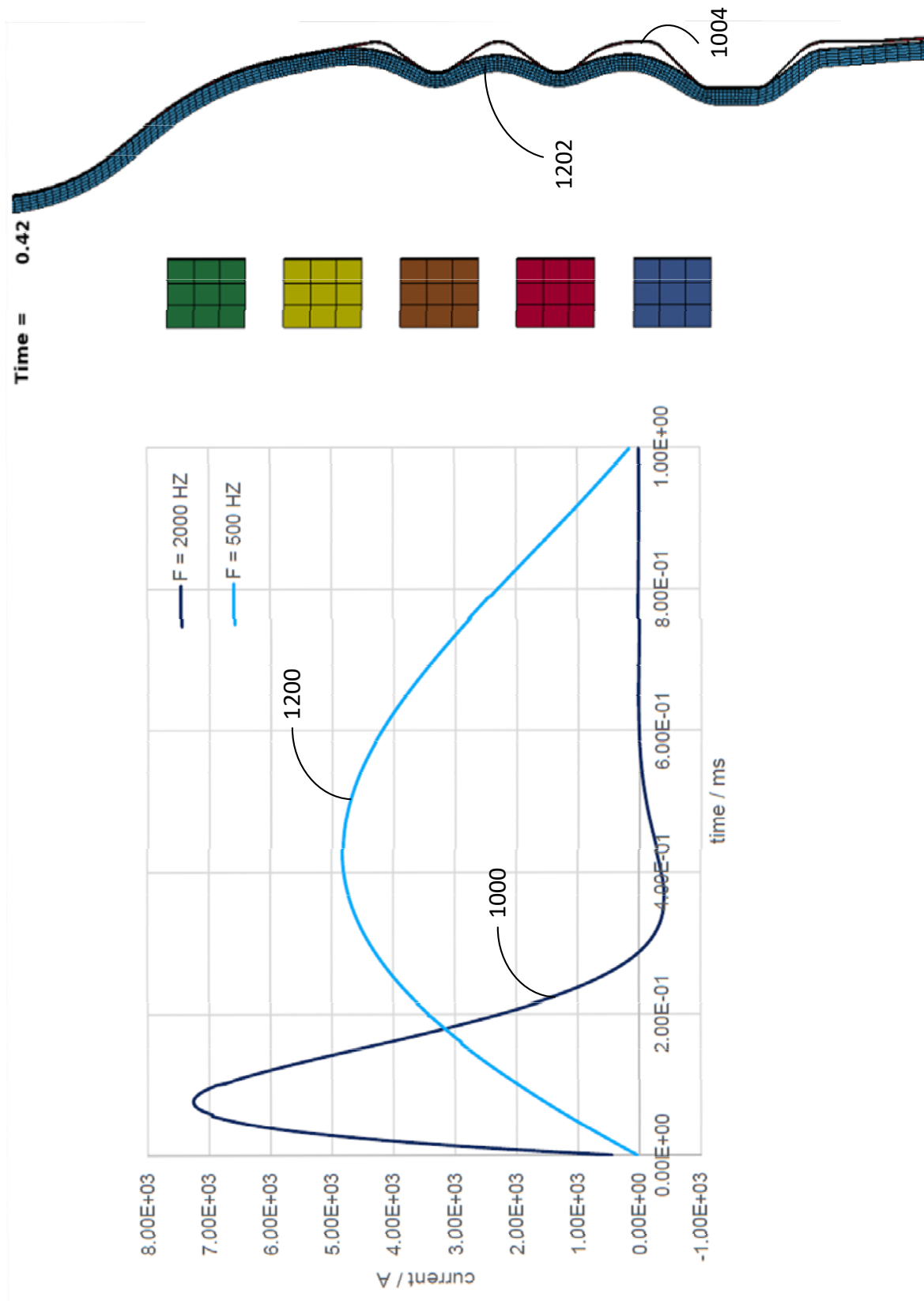


FIG. 11B

FIG. 11A



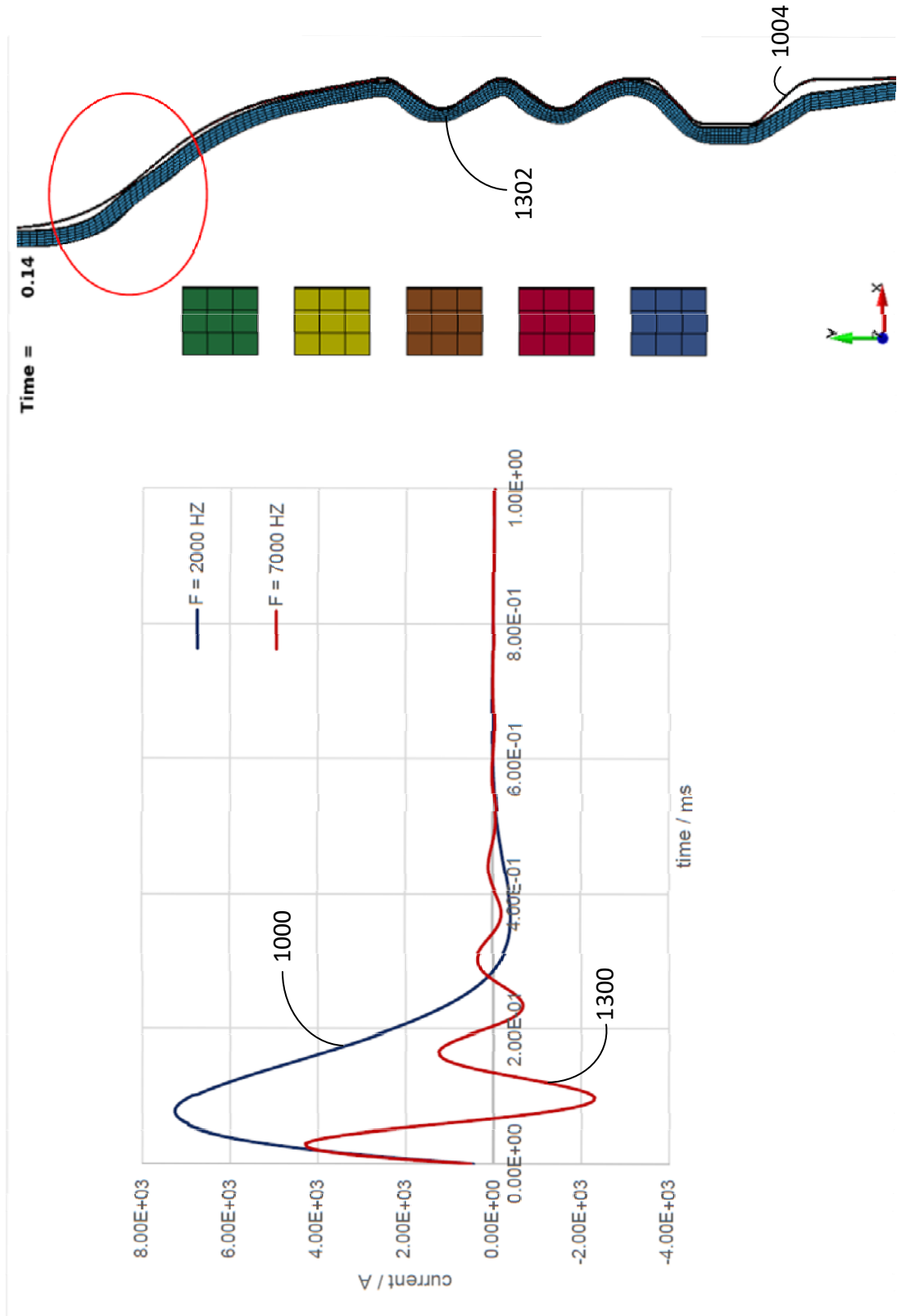


FIG. 13B

FIG. 13A

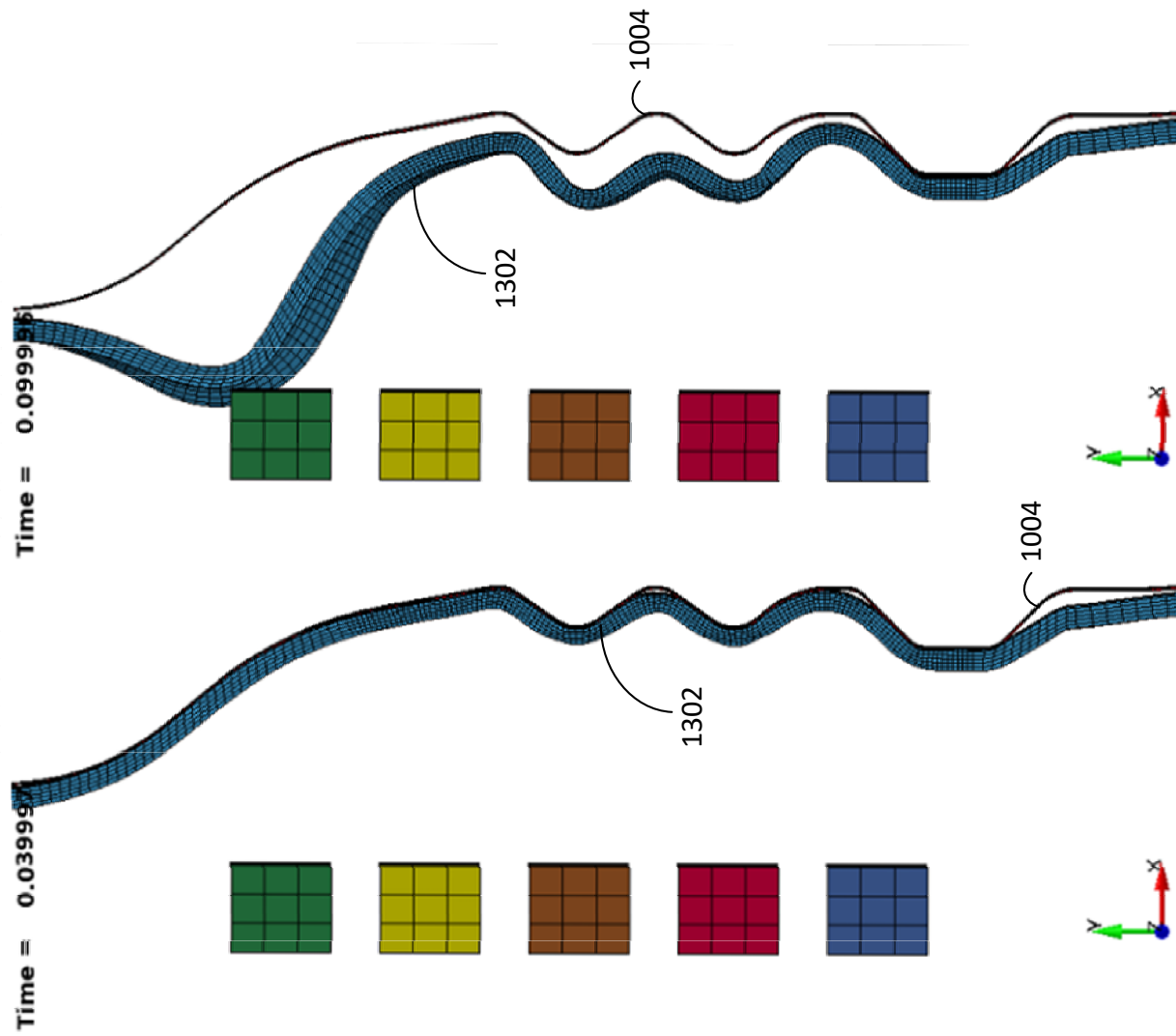


FIG. 13D

FIG. 13C

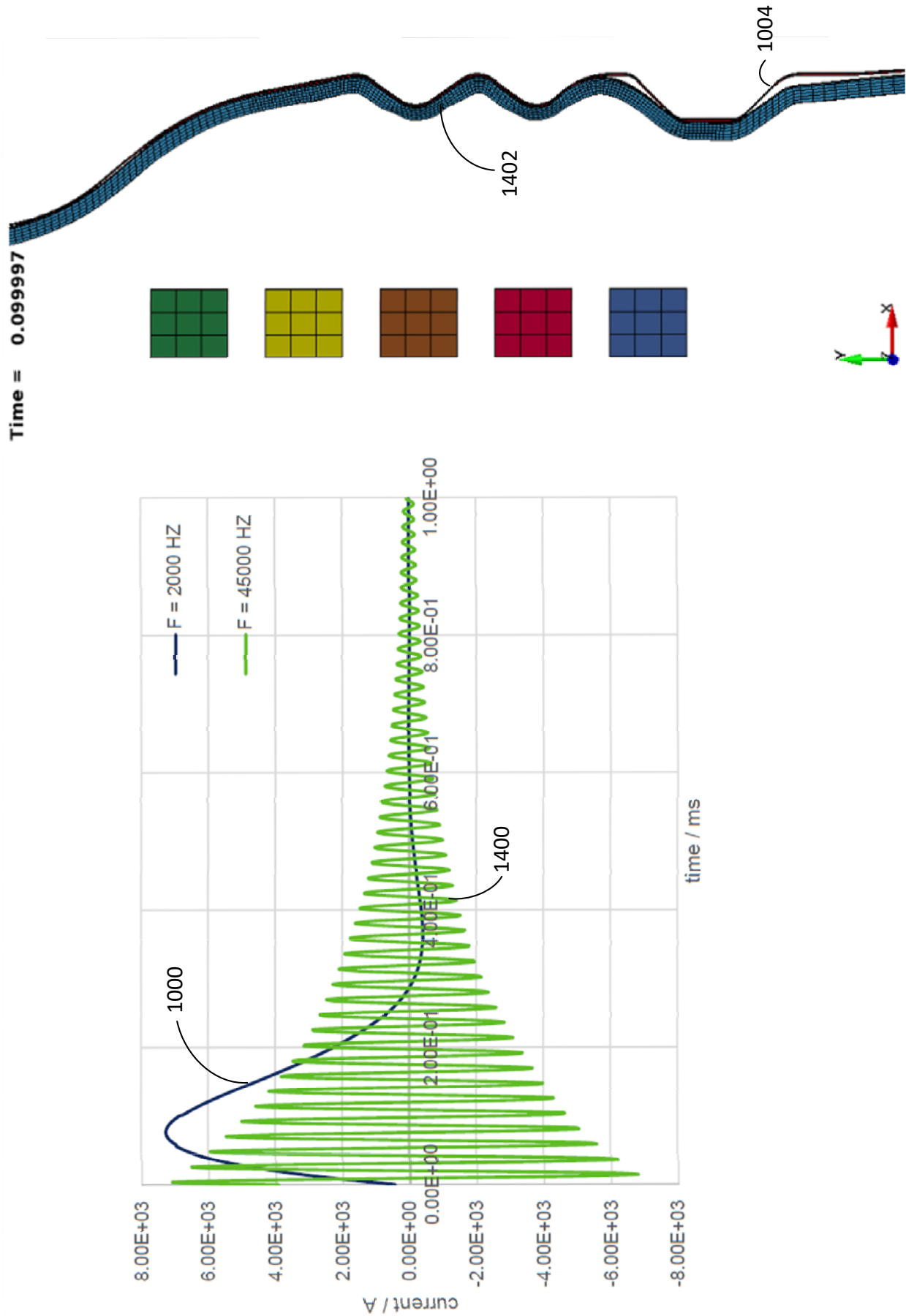


FIG. 14B

FIG. 14A

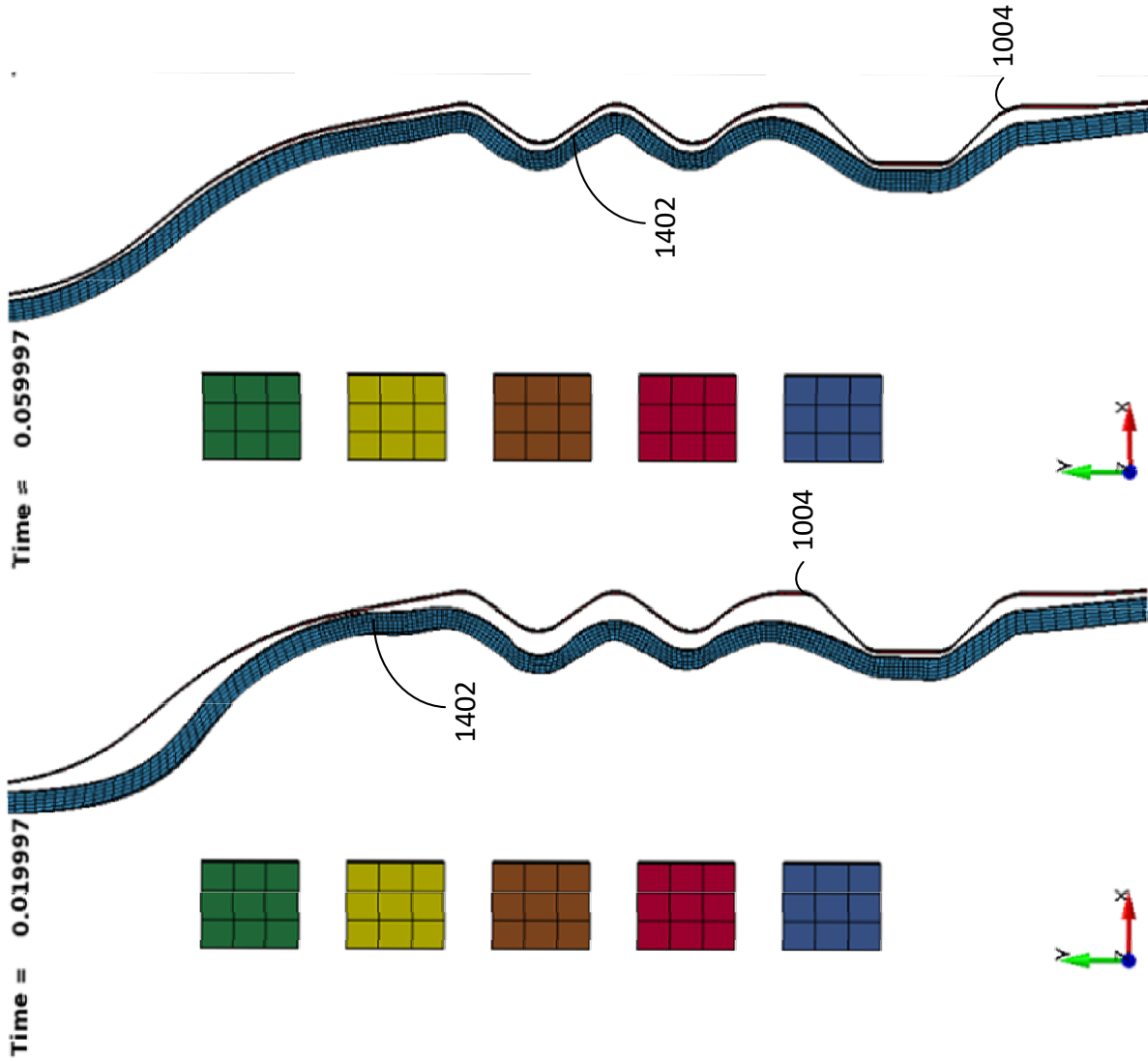


FIG. 14D

FIG. 14C

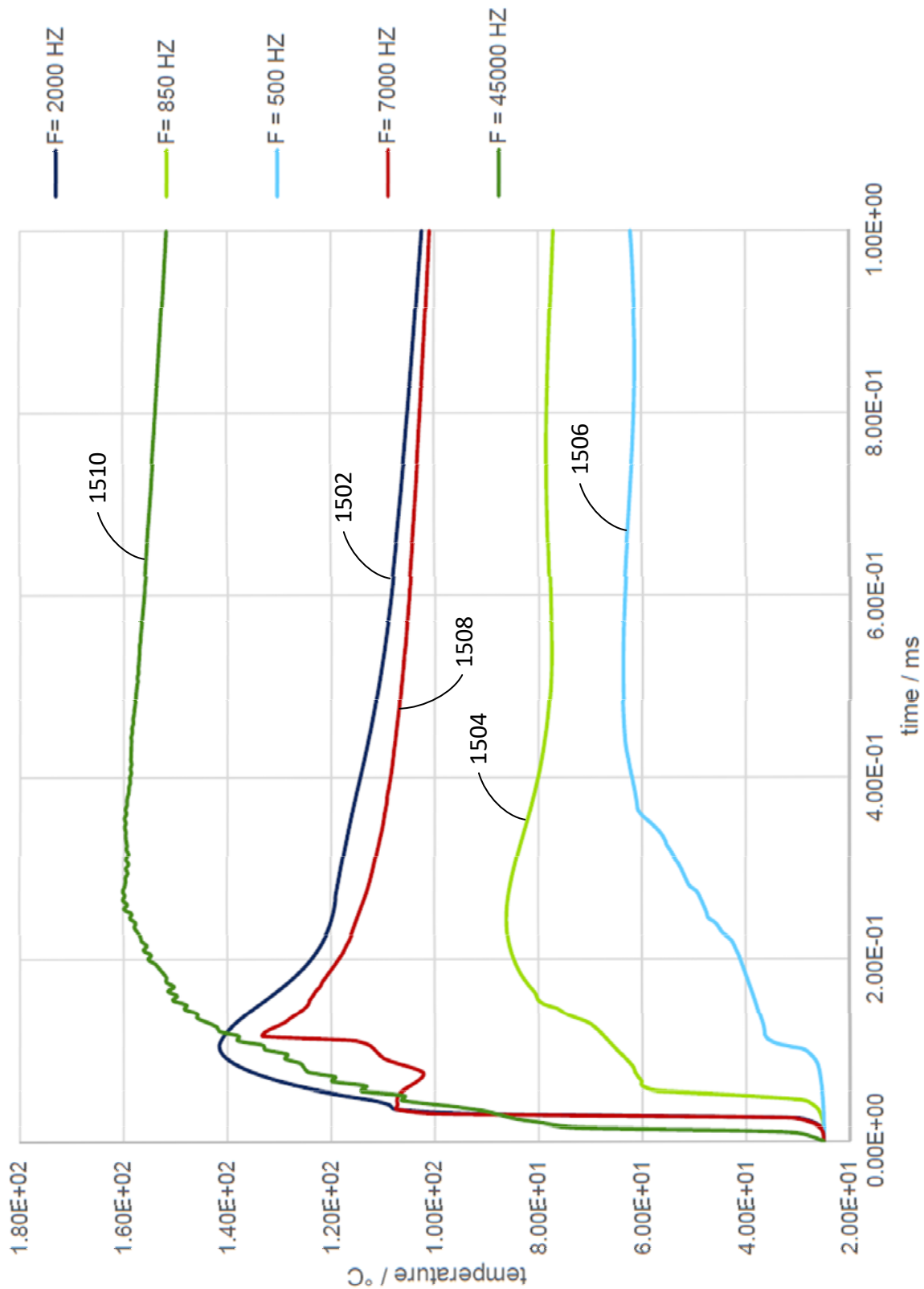


FIG. 15



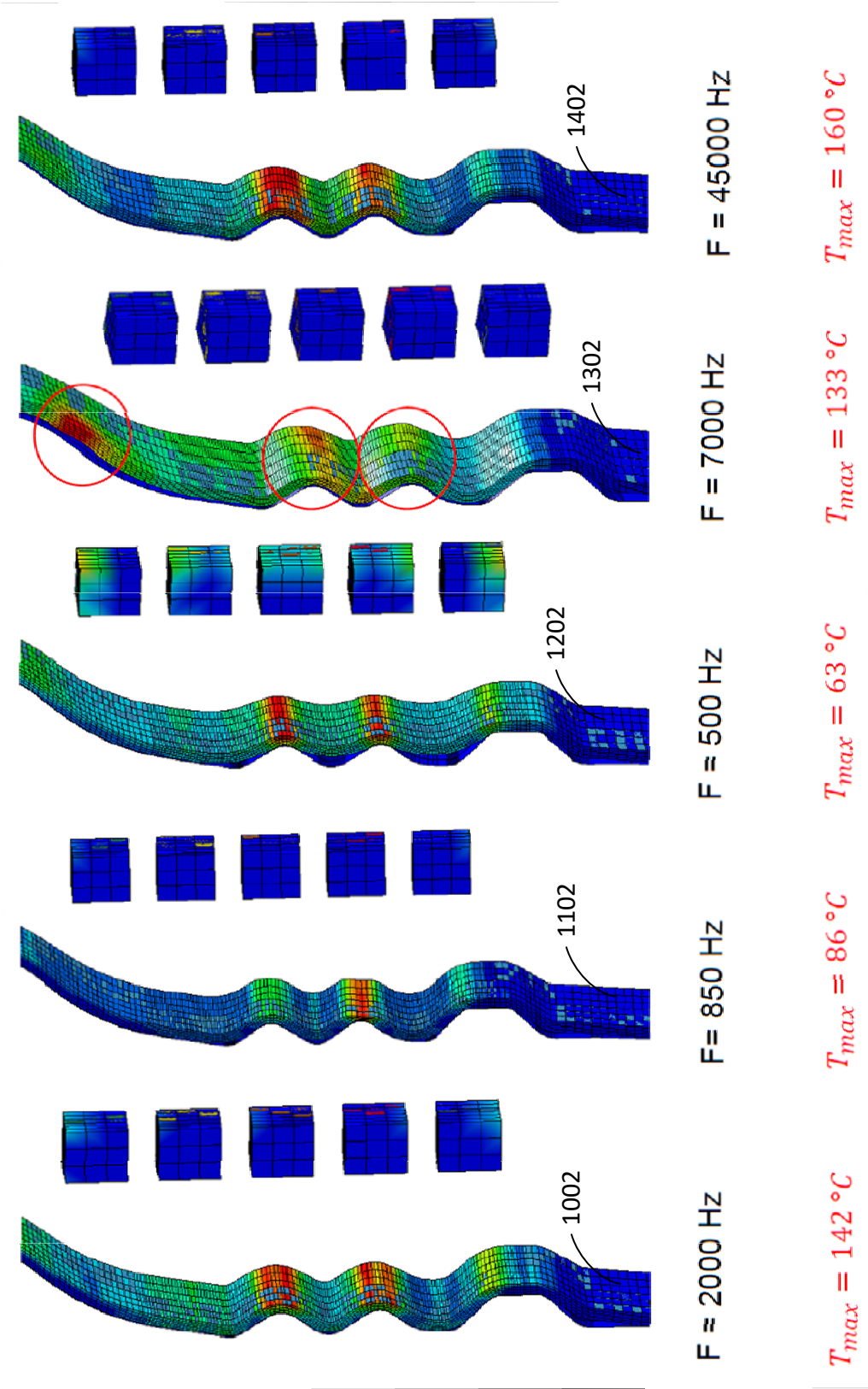


FIG. 16

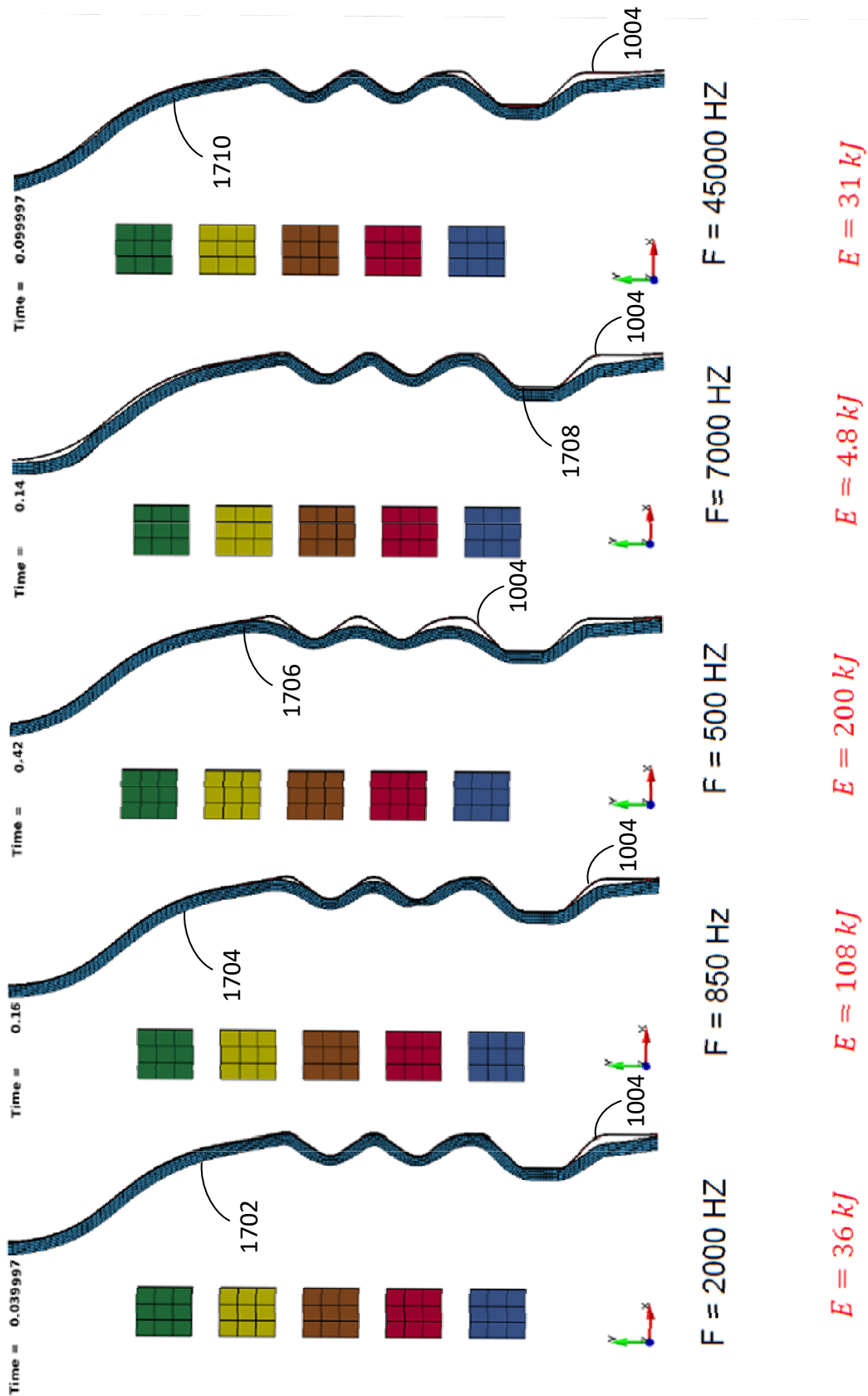


FIG. 17